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THE EFFECTS ON THE GRASSHOPPER, *MELANOPLUS MEXICANUS MEXICANUS* (SAUSS.) (ORTHOPTERA: ACRIDIDAE), OF VARYING THE NITROGEN CONTENT IN ITS FOOD PLANT[1]

BY D. S. SMITH[2] AND F. E. NORTHCOTT[3]

Abstract

Melanoplus mexicanus mexicanus (Sauss.), from time of hatching, was fed on wheat (Renown) grown in nutrient solutions of varying nitrogen content. Some wheat was produced with an average nitrogen content of 6.16% (dry weight), some with 4.29%, and some with 3.33%. Survival and development were greatest on the high nitrogen wheat, least on the low. On the low nitrogen wheat no individuals developed beyond the last nymphal instar. Neither weight of adults nor the sex ratio was affected by the various foods. Females fed on wheat with a high nitrogen content laid more eggs but the viability of the eggs was not affected.

Introduction

Insects are known to differ in such biological factors as survival, rate of development, and number of progeny, depending upon the food they eat. In phytophagous insects these differences may be caused by feeding on plants of different genera, of different species, or even of different varieties of a species. Among innumerable papers on this might be mentioned those on Orthoptera by Hodge (11), Chauvin (3), Smith, Handford, and Chefurka (19), and Tauber, Drake, and Decker (20); those on Lepidoptera by Basu (2) and Seamans and McMillan (18); and one on Coleoptera by Hill (10).

Some attempts have been made to determine the contributing factors. Webster, Seiglinger, and Davies (21) made extensive chemical analyses of a number of varieties of sorghum but found no substances that could be correlated with the differences in longevity and fecundity found by Dahms (5) in chinch bugs feeding on these varieties. Creighton (4) stated that *Alabama argillacea* (Hbn.) underwent a prolonged developmental period and suffered a very high mortality rate on zinc- and copper-deficient plants (presumably cotton). Pepper and Hastings (17) suggest that sterility in the sugar-beet webworm is connected with an insufficient amount of linoleic acid in the host plant.

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Much of this work has been concerned with the amount of nitrogen in the food plant. Mumford and Hey (16) claim that, in general, a plant with a high nitrogen content stimulates reproduction in insects feeding on it. Evans (8) has correlated the rate of reproduction of an aphid, *Brevicoryne brassicae* (L.), with the nitrogen content of the host. Haseman (9) reported that the chinch bug would mature faster and produce more offspring on nitrogen-deficient corn. On the other hand he found that *Toxoptera graminum* (Rond.) produced very few offspring on nitrogen-deficient plants.

This question of the factors in the host plant that affect the insect attacking it is important in developing varieties of plants resistant to insects or unsuitable for them. In some cases resistance may depend on such a nutritional factor (15). Dahms (5) has shown that the chinch bug survives better and has a greater fecundity on susceptible varieties of sorghum, and Davidson (6) has had similar results with aphids on beans. It has been suggested that the nitrogen content of the cell sap of plants is an important factor in the susceptibility of the plant to insect attack (1, 7, 12).

The present study investigates the effect of the amount of nitrogen in a food plant on the lesser migratory grasshopper, *Melanoplus mexicanus mexicanus* (Sauss.). Wheat was grown in nutrient solutions to produce plants containing various amounts of nitrogen. These plants were used as the sole food for the grasshopper during the whole of its nymphal and adult life.

Materials and Methods

Renown wheat was grown outdoors in asphalt-coated basins filled with vermiculite (Terralite). Seeds were planted in this material and watered with distilled water until they sprouted. Then nutrient solutions prepared with distilled water were supplied to the basins every six hours by an automatic subirrigation method adapted from one described by Lott (13). Three nutrient solutions were used: high nitrogen, low nitrogen, zero nitrogen (Table I).

TABLE I

COMPOSITIONS OF NUTRIENT SOLUTIONS FOR WHEAT

Stock solution		Zero nitrogen, ml./liter	Low nitrogen, ml./liter	High nitrogen, ml./liter
KH_2PO_4	1 *M*	—	6.45	—
$Ca(NO_3)_2$	1 *M*	—	0.25	31.50
$MgSO_4$	1 *M*	2.00	2.00	2.00
$(NH_4)_2SO_4$	1 *M*	—	0.10	—
$CaCl_2$	1 *M*	—	2.75	—
$NH_4H_2PO_4$	1 *M*	—	—	6.45
NH_4NO_3	1 *M*	—	—	33.50
KNO_3	1 *M*	—	—	6.45
K_2SO_4	0.25 *M*	10.00	—	—
$Ca(H_2PO_4)_2$	0.05 *M*	40.00	—	—
$CaSO_4$	0.01 *M*	200.00	—	—

To each liter of these solutions was added one milliliter of a stock solution of micronutrient elements prepared as follows:—

Ingredient	*Grams per liter*
H_3BO_3	2.86
$MnCl_2 . 4H_2O$	1.81
$ZnSO_4 . 7H_2O$	0.22
$CuSO_4 . 5H_2O$	0.08

Ferrous sulphate was applied to the surface of the vermiculite in the basins at the rate of 10 to 15 p.p.m. of nutrient solution at least once a week. The solutions were completely replaced every two weeks. Weekly measurements of the pH of the solutions showed a range of 4.8 to 6.6, so that no adjustment was considered necessary.

Total nitrogen determinations were made by the method of Ma and Zuazaga (14). Several samples were taken from the wheat grown in each nutrient solution at intervals from 10 to 30 days after germination, the period during which the wheat was used as food. The samples were dried at room temperature, ground, and then further dried to constant weight in an oven at 98° C.

Field-collected eggs of *M. m. mexicanus* were hatched in the laboratory and the nymphs were placed in two-quart sealers. The glass top of the sealer was replaced by wire mesh screening, and an inch of soil was packed in the bottom. The sealers were kept outdoors and shielded with boards from rain and the heat of the midday sun.

Ten sealers, each containing 10 nymphs, comprised one series, and one series was devoted to each type of food. On June 11 three series were started and they are designated below as High N, Low N, and Zero N_a. The mortality rate in the Zero N_a series increased so rapidly that two additional series were started, Zero N_b on July 22, and Zero N_c on Aug. 1. Cuttings from the wheat from the different treatments were supplied to the grasshoppers two to four times daily. The sealers were examined daily and molts and deaths recorded. Each series continued until there was no further oviposition and most of the insects had died.

The soil in the sealers was sifted every few days and the egg pods were removed to cold storage. After about four months at 35°–40° F. they were placed at room temperature. The numbers hatching were recorded as were also the number of eggs that did not hatch.

Nitrogen Content of Wheat

The ranges of total nitrogen content of wheat from the high nitrogen and low nitrogen treatments are quite distinct (Table II). There is, however, an overlapping between that from the low nitrogen treatment and that from the zero.

TABLE II

TOTAL NITROGEN CONTENTS OF WHEAT GROWN IN THREE NUTRIENT SOLUTIONS AS PERCENTAGES OF DRY WEIGHTS

Nutrient solution	Number of determinations	Nitrogen content	
		Range	Average
High nitrogen	42	7.41–5.07	6.16
Low nitrogen	53	4.62–3.79	4.29
Zero nitrogen	45	4.01–2.29	3.33

Survival

The trend of survival of the grasshoppers in the five series during the whole period of nymphal development is shown in Fig. 1.

The grasshoppers on the High N series consistently showed the highest survival and those on the Zero N series the lowest. In Series Zero N_b all individuals were dead in 15 days and in Zero N_a 96% were dead after 25 days. Mortality did not increase so rapidly on series Zero N_c, nor was the final mortality as great as on the other two. This series differed from all others in that the nymphs were hatched from eggs that were collected from a different location and it was started later in the season.

Development

The average durations of the nymphal stadia of the grasshopper are shown in Table III. Figures are not given for the Zero N series, as so few individuals

TABLE III

RATES OF DEVELOPMENT OF *M. m. mexicanus* ON WHEATS GROWN IN SOLUTIONS OF HIGH AND OF LOW NITROGEN CONTENT

Nutrient series	Average nitrogen content of wheat	Average number of days per instar					Average duration of nymphal period in days
		1st	2nd	3rd	4th	5th	
High N	6.16	12	7	6	8	16	49
Low N	4.29	13	7	8	15	18	61

in these lived past the second instar and none completed development. Development was more rapid in the High N series, particularly in the later instars.

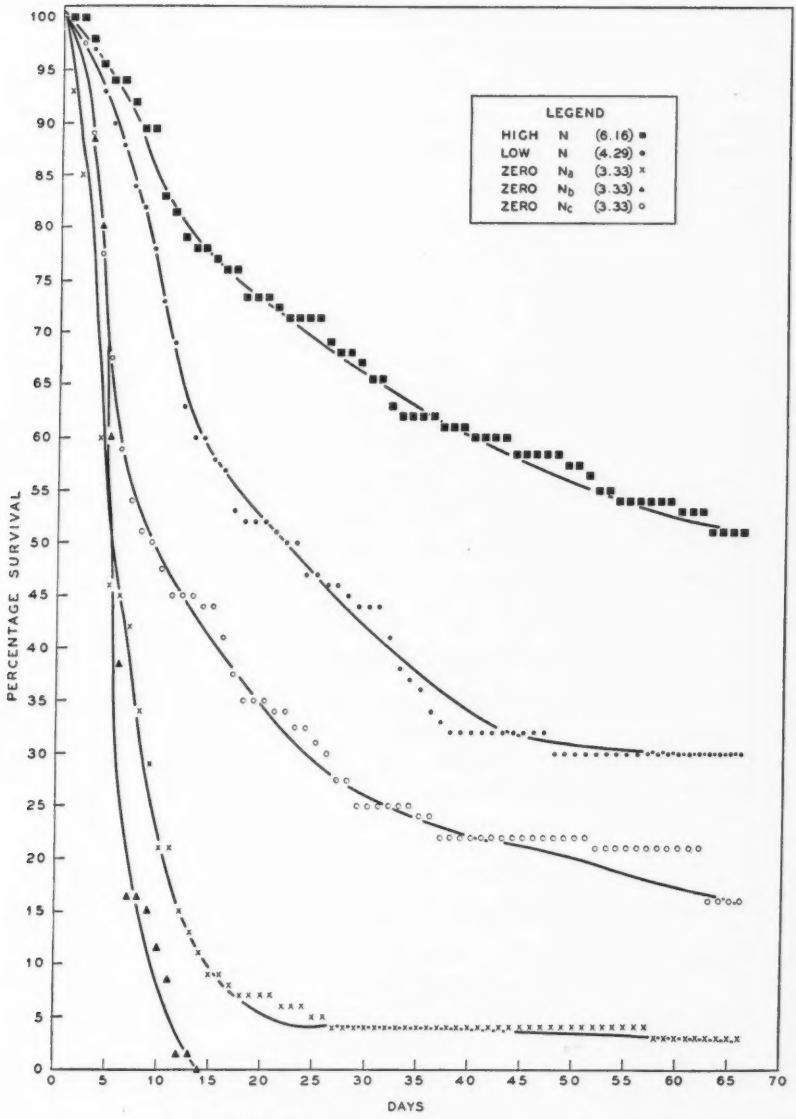

FIG. 1. Trend of survival of *M. m. mexicanus* during period of nymphal development on wheats grown in nutrient solutions of different nitrogen contents.

The number of individuals developing to the adult stage on the high nitrogen wheat was significantly greater than the number that developed on the others (Table IV).

TABLE IV

SURVIVAL OF *M. m. mexicanus* AND NUMBERS OF ADULTS DEVELOPING

Nutrient series	Average nitrogen content of wheat	Number surviving after 66 days	Percentage survival	Number of adults	Percentage adults*
High N	6.16	44	48	44	48
Low N	4.29	30	30	29	29
Zero N_a	3.33	4	4	0	0
Zero N_b	3.33	0	0	0	0
Zero N_c	3.33	13	16	0	0

* *Least significant difference (5% level), 19.*

In the Zero N series no adults appeared and most individuals failed to develop beyond the second instar. Development appeared to be more uniform on the High N series, as 90% of those reaching the adult stage did so within 11 days of each other. In the Low N series 25 days elapsed after the appearance of the first adult before 90% were in this stage.

Weight of Adults

Newly molted adults were weighed individually as they appeared. The average weights (Table V) indicate no differences as a result of the different foods. It is unusual, though, for the weight of the male to exceed that of the female, as it does in the Low N series.

TABLE V

AVERAGE WEIGHTS OF NEWLY EMERGED ADULTS

Nutrient series	Average nitrogen content of wheat	Male	Female
High N	6.16	0.1532 gm.	0.1649 gm.
Low N	4.29	0.1613 gm.	0.1561 gm.

Sex Ratio

The numbers of males and females appearing on the High N and the Low N series (Table VI) did not differ significantly from a 50 : 50 ratio and revealed no differential effect of the food on sex.

TABLE VI

NUMBERS OF MALES AND FEMALES IN SURVIVING ADULTS

Nutrient series	Average nitrogen content of wheat	Male	Female	Total
High N	6.16	25	19	44
Low N	4.29	11	18	29

Fecundity and Egg Viability

The numbers of eggs laid by females reared on wheat from the high nitrogen and the low nitrogen treatments as well as the number that hatched are shown in Table VII. Females fed on wheat from the high nitrogen treatment laid considerably more eggs than those fed on low nitrogen wheat. The relative viability of the eggs was measured by the percentage hatch; and as the two groups of eggs were kept together under identical conditions, the figures are considered to be a reliable estimate. The different foods seem to have no effect on viability, the percentage hatch being approximately the same for the two series.

TABLE VII

EGG PRODUCTION AND PERCENTAGE HATCH

Nutrient series	Average nitrogen content of wheat	Total number of eggs	Number of females	Number of eggs per female	Number of eggs hatched	Percentage hatch
High N	6.16	1094	19	57.6	490	44.8
Low N	4.29	624	18	34.7	292	46.8

Conclusion

This study clearly indicates a positive correlation between an increase in the nitrogen content of the wheat and a greater vitality of *M. m. mexicanus* as measured in terms of survival, development, and egg production. The nitrogen content of the food plant had no effect on egg hatchability.

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